E7.5-10.3.22
CR-142924

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Environmental Monitoring from Spacecraft Data		5. Report Date June 1975 6. Performing Organization Code
7. Author(s) R.H. Rogers et. al		8. Performing Organization Report No. BSR 4183
9. Performing Organization Name and Address Bendix Aerospace Systems Div. 3621 South State Rd. Ann Arbor, Mich. 48107		10. Work Unit No. 11. Contract or Grant No. NAS 5-20942 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Goddard Space Flight Center Greenbelt, Md. 20771		Special Report 14. Sponsoring Agency Code

15. Supplementary Notes

Published in proceedings of Symposium on Machine Processing of Remotely Sensed Data; Purdue University; June 1975.

16. Abstract

LANDSAT CCTs were used as a basis for inventorying land use within each of the Ohio-Kentucky-Indiana Regional Commissions, 225 drainage areas, and nine counties. Computer tabulations were produced to obtain the area covered by each of 16 land-use categories within 225 drainage areas. The 16 categories were merged into ten categories and mapped at a scale of 1 in. = 5,000 ft, with detail to 0.44 hectares for the 2,700 sq. mi. region. These products were produced in less than 90 days, at a cost of $20,000. It is not uncommon to find single counties spending this much to map similar categories within a much smaller area.

(E75-10322) ENVIRONMENTAL MONITORING FROM SPACECRAFT DATA (Bendix Corp.) 11 p HC $3.25 CSCL 13B

N75-26466

Unclas

G3/43 00322

17. Key Words (Selected by Author(s))	18. Distribution Statement
Water Quality, ERTS, Computer Processing, Land Use.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
		10	

ENVIRONMENTAL MONITORING FROM SPACECRAFT DATA

R. H. Rogers*, C. L. Wilson*, L. E. Reed*, N. J. Shah*,
R. Akeley*, T. G. Mara**, V. Elliott Smith***

*Bendix Aerospace Systems Division, Ann Arbor, Michigan;
**Ohio-Kentucky-Indiana Regional Council of Governments,
Cincinnati, Ohio;
***Cranbrook Institute of Science, Bloomfield Hills, Michigan

ABSTRACT

Section 208 of the Federal Water Pollution Control Act Amendments of 1972 provided the opportunity and funding to fight water pollution through the use of regional water quality planning. A common requirement of the 208 program is to develop a capability of predicting water quality in the rivers and lakes resulting from existing and potential land-use policies. To achieve this capability, the Ohio-Kentucky-Indiana (OKI) Regional Council of Governments is developing a deterministic model capable of predicting sediment and nutrient flow into the waterways. An essential input to OKI's model is an accurate map of land use within the watersheds. This information was obtained by OKI through the machine processing of LANDSAT-1 digital tapes. Computer tabulations were generated to obtain area covered by each of 16 land-use categories within 225 drainage areas. The 16 categories were merged into 10 categories and mapped at a scale of 1 inch = 5,000 feet with detail to 0.44 hectares (1.1 acres) for the 2,700-square mile region. The map products and data were produced within a period of less than 90 days at a cost of $20,000, a significant improvement in dollars and time over conventional mapping techniques.

BACKGROUND

State and federal agencies are becoming increasingly alarmed over the loss in water quality in many of our public lakes and rivers. Much of this loss is a direct result of pollution generated by man and the increased sediment and nutrient runoffs into the rivers and lakes resulting from urbanization in the watersheds. It is now realized that our water resources are not inexhaustible and that land development in the watersheds must be planned if the conflict between utilization of our water resources and maintenance of the quality of our lives is to be resolved.

To provide for this needed planning, the Federal Water Pollution Control Act Amendments of 1972 created several programs to fight water pollution. Under provisions of Section 208 of that act (EPA, 1974), regional councils of government such as OKI were given the opportunity and the funding to undertake regional water quality planning. The new 208 program (OKI 1974) differs from past HUD-financed water and sewer planning in that this new EPA-administered program deals with all sources of pollution, not just pollution from municipal sewerage systems. Other sources of pollution for which planning responsibility is given are industrial discharges and what are termed "non-point" sources. These non-point sources include sedimentation and runoff of pesticides and fertilizers from agricultural areas, urban runoff, erosion from construction sites, and leachates from septic tanks.

A common requirement of the 208 programs and programs of other governmental agencies concerned with the maintenance and control of water quality is the development of a knowledge of the interrelationships between the water quality parameters (turbidity, chlorophyll concentrations, etc.) and land-use parameters (land-use categories and coverage, etc.).

To obtain this information, OKI is developing a deterministic model capable of predicting water quality in rivers and lakes resulting from existing and potential land-use policies. The inventory of present land use together with population projections will provide OKI a basis for developing future land-use maps. Given a future land use, the water quality model will be used to predict the imlact of future development on water quality. This analysis will aid OKI in identifying critical areas where alternatives will have to be developed to minimize any deleterious impact on water quality. This may involve redirecting growth to other areas where the impact might not be so severe, or changing the character of the growth to minimize any harmful impact on water quality. The water quality plan will, in effect, contain a significant land-use planning element. The 208 water quality planning program, in fact, may provide the most rational basis for land-use planning available to date.

Accurate water and land-use parameters are essential in the development and application of the water quality model.

While many factors influence water quality, a dominating one is the use of land adjacent to and surrounding the lakes and rivers, the "drainage areas." During periods of rain or thaw, this area discharges sediment and nutrients directly to the water bodies by means of surface runoff or storm drainage. Each land-use category has its own special characteristic (EPA-1430, 1973) which is important in the calculation of the quantity and quality of storm-water runoff. For example, fertilized lawns (tended grass) and paved streets discharge more nutrients, especially phosphorus, than do rangeland (untended grass) and forested land. Cropland is often tilled in the spring when rainfall is heaviest and absorbs much of the water, but erosion in the form of sediments, which includes pesticides and fertilizer, are washed into nearby streams. This differs from what happens in a center city area where virtually all of the ground is covered by pavement and buildings and little or none of the water is absorbed into the earth. Instead, the water flows rapidly into storm sewers, carrying with it dirt from streets and buildings.

To establish sediment and nutrient flows from the drainage areas into the waterways, accurate information on drainage area land use is essential. Land-use information presently available to planning agencies is not adequate for water quality planning purposes. In almost every case, agricultural and vacant land has been lumped into one category such as miscellaneous. Urban land uses often are not identified (categorized) in terms usable for water quality planning. Also, most 208 program planning areas are extremely large. The OKI Region covers 7,024 sq km (2,712 sq mi) and contains 225 drainage areas. For these reasons, OKI decided that the traditional techniques for land-use inventory - field inspection and interpretation of aerial photographs - are impractical in that they are too costly in terms of dollars and time. In its quest to evaluate new sources and techniques for obtaining the needed land-use information, OKI established and accomplished the following two goals:

- Produced a 10-category land-use map of the OKI regional area showing: rangeland, fallow cropland, water, cropland, two categories of forest land, core city/industrial, inner city, urban, and suburban. The smallest detail mapped was 0.44 hectare (1.1 acres) and the map scale was 1 in. = 5,000 ft.
- Produced computer tabulation of area covered by 16 land-use categories within 225 drainage areas and nine counties.

OKI achieved its mapping goals within a period of 90 days at a cost of only $20,000, a significant improvement over conventional techniques.

OKI REGION

The OKI objectives were achieved through the machine processing of the 14 April 1973 LANDSAT-1 scene shown in Figure 1. The OKI region shown in this scene consists of the Ohio Counties of Hamilton, Clermont, Butler, and Warren; the Indiana Counties of Dearborn and Ohio; and the Kentucky Counties of Boone, Kenton, and Campbell. This 2,712-sq mi region centered around Cincinnati is expected to increase its population to over 2,000,000 by the year 2000, a 35% growth from its present figure of about 1,600,000. The area is characterized by its many low hills and dense forest cover. The Ohio River and its tributaries drain the OKI region. The Ohio, Great Miami, and Little Miami rivers can also be seen in the LANDSAT image of the region. All of the rivers and lakes in the region are highly valued for recreational and residential uses. Increasingly heavy public use makes it vital that water quality consideration remains as one of OKI's highest planning priorities.

MACHINE PROCESSING OF LANDSAT DATA

The need for faster and more economical mapping of water quality and land use has led Bendix into evaluating computer target "spectral recognition" techniques as a basis for automatic target categorization and mapping. The categorization techniques (Dye, 1974, 1975; Rogers, 1974, 1975) have been under continued development at Bendix for the past 8 to 10 years, primarily using aircraft multispectral scanner data. More recently, LANDSAT/MSS and Skylab/EREP-S192 data have been used.

BENDIX DATA CENTER

The elements of the Bendix Data Center used to process data for this study are shown in Figure 2 and include: a Bendix Datagrid® Digitizer System 100 for digitizing graphical data, a Bendix Multispectral-Data Analysis System (M-DAS) for the analysis of LANDSAT "computer-compatible tapes" (CCTs), and a Cal Comp Plotter for the production of land-water categorized maps from the processed LANDSAT tapes. A Gerber Series

40 Plotting Table is also used for this mapping function. M-DAS has been discussed (Johnson, 1974) in detail previously.

The nucleus of the M-DAS is a Digital Equipment Corporation PDP-11/35 computer with 28K words of core memory, one 1.5M-word disc pack, two nine-track 800 bit-per-inch (bpi) tape transports, and a DECwriter unit. Other units are an Ampex FR-2000 14-track tape recorder, a bit synchronizer and tape deskew drawers which can reproduce up to 13 tape channels of multispectral data from high-density tape recordings, a high-speed hard-wired special-purpose computer for processing multispectral data, a 9 1/2-in. drum recorder for recording imagery on film, and a color moving-window computer-refreshed display. M-DAS is the result of an evolutionary program initiated by Bendix in 1967 and is dedicated to the processing of remote sensing data.

PROCESSING STEPS

The data processing steps used (Figure 2) and the results achieved in transforming LANDSAT CCTs into the desired land-use maps and data are briefly summarized in the following paragraphs.

Establish Map Categories

The first step in the development of the OKI land-use map was to locate and designate to the computer a number of LANDSAT picture elements or "pixels" that best typified the land-water categories of interest, the "training areas." These areas of known characteristics were established from aerial photographs and ground survey data, and were located on the LANDSAT CCTs by viewing the taped data on the M-DAS TV monitor. The coordinates of the training areas were designated to the computer by placing a cursor over the desired area and assigning a training area designation, category code, and color code. Several training areas, typically 20 to 50 pixels in size, were picked for each category, with each pixel corresponding to a ground coverage of 57 x 79 m. The color code was used in later playback of the tapes when the computer-categorized data are displayed in the designated colors.

Develop Processing Coefficients

The LANDSAT spectral measurements within the training area boundaries were edited by the computer from the CCT and processed to obtain a numerical descriptor (computer-processing coefficients) to represent the spectral characteristics of each target category. The descriptors (Dye, 1974) included the mean signal and standard deviation for each LANDSAT band and the covariance matrix taken about the mean. The descriptors were then used to generate a set of processing coefficients for each category. In automatic-category processing, the coefficients are used by the computer to form a linear combination of the LANDSAT measurements to produce a variable whose amplitude is associated with the probability of the unknown measurement being from the target sought. In category processing, the probability of a LANDSAT pixel arising from each one of the different target categories of interest is computed for each pixel and a decision, based on these computations, is reached. If all the probabilities are below a threshold level specified by the operator, the computer will decide that the category viewed is unknown (uncategorized).

The categorical processing of multivariate data at Bendix is carried out using a maximum likelihood procedure under multivariate normal hypothesis. The implementation of this procedure (Dye, 1975) for M alternatives involves evaluation of M density equations and acceptance of the alternative with the greatest density. The direct evaluation of each density equation requires (N + 1) times N multiply and add operations if implemented with N original variables. The direct method, thus, is slow and costly. The procedure used at Bendix greatly minimizes the computational load with no sacrifice in computational accuracy. During the decision process, the observation is subjected to a principal component transformation derived for a given group, and another transformation in which the inverse of the covariance matrix is diagonalized with respect to the covariance matrix of the remaining groups. The first transformation gives the direction of maximum variance of the given group with respect to the background (the remaining groups). When the decision process is carried out, the computation for each group now involves only N + 1 add and multiply operations. In addition to the cost-effectiveness, it also permits an increase in absolute accuracy by permitting dimensionality reductions, since an eigen value of less than one from the second transformation only hinders the accuracy of the classification scheme and, hence, the associated components for an eigen value of less than one are rejected during computations.

Evaluate Selection of Training Areas and Processing Coefficients

Before producing categorized data for the entire OKI region, a number of tests were applied to evaluate the computer's ability to perform the desired interpretation. The tests included generating categorization-accuracy tables and viewing the processed imagery on the M-DAS TV monitor. Selection of training areas, generation of accuracy tables, and evaluation of processing

results through use of computer printouts and the TV monitor were iterative operations. The 10 primary land-use categories listed below, in the order of their potential for discharging natural and human sources of nutrients, resulted from the LANDSAT processing.

- Core City/Industrial - Most dense industrial and commercial area, asphalt, concrete, gravel, etc., 0% vegetation.
- Inner City - Second-most dense industrial and commercial area, 1 to 10% vegetation cover.
- Urban - Third-most dense industrial and commercial area, also includes high-density residential area, 10 to 50% vegetation cover.
- Suburban - Fourth-most dense area, housing, isolated shopping center, greater than 50% vegetation cover.
- Cropland (3 categories).
- Fallow Cropland.
- Rangeland.
- Forestland (Density 1) - Mixed hardwood (deciduous) forest and softwoods.
- Forestland (Density 2) - Mixed hardwoods and softwoods.
- Water (5 categories) - Five categories of water are probably: deep clear; shallow water; and three categories corresponding to different sediment concentrations.

In addition to the 10 major categories noted above, cropland was separated into three crop categories and water into five categories. Ground-truth activities are underway to refine the identification of the crop and water categories.

Evaluation of processed results show that some urban categories become confused with non-urban categories; i.e., core city with water, urban with cropland, etc. However, the errors occur at random spots as "speckles" and, when viewed in context on a map grid, are easily corrected by an interpreter. This points up the additional need to transfer LANDSAT categorized data to a base map.

Generate Categorized LANDSAT Tapes

When satisfied with the categorization accuracy achieved on the land-water categories, the processing coefficients were placed into the computer disk file and used to process that portion of the LANDSAT CCTs covering the OKI region. This step in the categorization processing resulted in new or categorized CCTs, where each LANDSAT pixel was represented by a code designating one of the 16 land-water categories. These 16 categories were merged into the 10 primary categories noted previously and mapped at a scale of 1 in. = 5,000 ft for the OKI region. Computer tabulations were also extracted from the categorized tapes to obtain a quantitative measure of land use within the drainage areas.

Produce Categorized Map Overlays

To produce categorized data that will directly relate to a base map, the categorized CCTs were submitted to a second stage of processing. In this stage, new tapes were generated that had data corrected for earth rotation and a format compatible with a computer-driven Cal-Comp Plotter. These tapes, when played back by the computer, caused overlays of a specified land-water category to be drawn by the plotter (see bottom image in Figure 2) on mylar at a scale specified by the operator. Examples of these mylar drawings over a map of drainage areas near Cincinnati are shown in Figure 3. The examples show core city/industrial, water, and forestland categories at the original scale of 1:120,000. The overlays were photographically enlarged later to the final map scale of 1 in. = 5,000 ft. A diazochrome material was exposed through the black and clear category transparencies by a lithographic plate burner and ammonia developed to produce color-coded overlays. The color coding permitted multiple overlays to be used simultaneously over the base map.

A 10-category color coded land-use map was developed for the entire 7,024 sq km (2,712 sq mi) region at the full LANDSAT resolution (0.44 hectare or 1.1 acre pixels) and at a scale of 1 in. = 5,000 ft. The cost for this map was approximately $2.50 per square mile.

Four parameters were used in performing the geometric correction of LANDSAT data: spacecraft heading, spacecraft earth latitude, adjusted scan line length, and spacecraft altitude. The first three parameters only were available on the LANDSAT CCT. The heading, latitude, and adjusted scan line length were used to generate incremental coordinate translations of the LANDSAT data, scan line by scan line, to obtain along-track and cross-track corrections. The coordinate translation increases as the computer moves through the tape, and the rate of increase is a function primarily of spacecraft latitude. Provisions were made to vary the coordinate translation with adjusted scan line length, but experience has shown that the scan line

length varies little and the correction for scan line length has little effect on the data. An important parameter that was not on the tape is exact satellite altitude. This information is available in the Goddard processing facility when the tape is generated, but for some reason it is not placed on the tape. Bendix has attempted to establish a channel through which this information can be made available for tapes delivered to Bendix, but has been unsuccessful to date. Altitude variations can cause approximately ±0.5% variation in the cross-track scale and must be corrected. The approach used by Bendix was to generate one trial overlay (such as water boundaries) after all other corrections are made, overlay the trial overlay on a map, select at least two control points common to both the overlay and the map, and calculate a cross-track correction factor to compensate for satellite altitude variations.

Area Measurement Tables

Computer-generated area measurement tables, illustrated in Figure 4, were produced from the categorized data tapes to determine land use within the drainage areas. To accomplish this step, a procedure was developed by which the drainage area boundaries in earth coordinates (latitude and longitude) are first digitized (Figure 2) from watershed maps. The resulting digital tape is processed on M-DAS (Figure 2) to transform the earth coordinates to LANDSAT coordinates and to extract and tabulate land use from the categorized tape. The area measurement table provides the amount of land that falls within a particular category in terms of square kilometers, acres, and percentage of the total drainage area processed. These data provided a direct and useful input to OKI's water quality model where each category is assigned a "loading function" or pollution equivalent (EPA-1430, 1973). Eventually, by multiplying the extent of land use acreage in an area by these loading functions, the water quality model will calculate the extent of pollution emanating from these non-point sources.

Earth to ERTS Coordinate Transformation - There were three basic steps involved in the automatic referencing of ground coordinates to LANDSAT coordinates. The first step consisted of automatic retrieval of the latitude and longitude of carefully selected ground control points (GCPs) from a map through a digitizing process. The criteria for selecting these GCPs is that they can be easily and accurately identified on LANDSAT imagery. The second step consisted of converting the latitude and longitude of these GCPs to LANDSAT coordinates by using a theoretical transformation derived from known and assumed spacecraft parameters including: heading, scan rate, altitude, and a knowledge of earth rotation parameters. The LANDSAT coordinates and transformation matrices thus obtained are approximate, based on the use of the nominal spacecraft parameters. The approximately-derived LANDSAT coordinates and transformation are used, however, to identify the actual LANDSAT coordinates associated with the GCPs. To accomplish this, the coordinates of a GCP is input to the Bendix M-DAS. The approximate transformation computes the LANDSAT coordinates and displays the area on the TV monitor. Positional errors of the GCPs displayed to the operator are designated by a cursor to the computer, which uses the error measurement to derive an improved set of coefficients for the transformation matrix. This procedure is repeated on additional GCPs until the desired geometric accuracy is achieved. This rapid interactive procedure is essential for producing a transformation matrix that provides an accurate transformation of earth to LANDSAT coordinates.

CONCLUSION

Machine processing of LANDSAT data provides a rapid and economical means of mapping land use in watersheds of lakes and rivers.

Although additional improvements can and are being made in processing techniques to increase mapping rates and accuracy and to reduce cost, OKI has demonstrated the techniques and utility of LANDSAT for mapping watershed land use on an operational basis.

As there is still some confusion between some urban and non-urban categories as indicated by random misclassification (speckling), additional processing refinements are needed to improve separability of these categories.

Machine-assisted interpretation of LANDSAT tapes was found to be very fast. The analysis phase required about one day per LANDSAT scene. Once the analysis was completed and the processing coefficients were computed, the categorized tape was produced for a full LANDSAT CCT (2,500 square nautical miles) in less than 30 minutes. Boundaries of water drainage areas were manually digitized from maps of the OKI area at a rate of about six per hour. The computer extracted and tabulated land use within these areas at a rate of one every 3 minutes. The major time-consuming step in the production of the LANDSAT products was the generation of the map overlays for the region, which required about 3 weeks. In the near future, equipment and techniques will be in use that will permit this step to be accomplished within a day.

The machine-processing techniques permitted the nine-county OKI region to be mapped to 1-acre

detail for $20,000. With application of conventional techniques, it is not uncommon for a county to spend this much or more to map similar categories within a much smaller area. Additionally, conventional techniques based on manual interpretation of photography and field checks typically require a year or two to obtain a mapping product similar to that obtained by OKI within 90 days.

REFERENCES

Dye, R. H., "Multivariate Categorical Analysis," Bendix Special Report BSR 4149, 1974.

Dye, R. H. and C. S. Chen, "Divergence Analysis of Bendix Feature Extraction Classification System," Proceedings of Purdue Symposium on Machine Processing of Remotely Sensed Data, June 3-5, 1975.

Johnson, R. H., "M-DAS Multispectral Data Analysis System," Bendix Report BSR 4146B, September 1974.

Ohio-Kentucky-Indiana Regional Council of Governments, "Clean Water; What You Can Do," October 1974.

Rogers, R. H., Reed, L. E., and N. J. Shah, "Automatic Classification of Eutrophication of Inland Lakes from Spacecraft Data," Proceedings of the Ninth International Symposium on Remote Sensing of Environment, Vol. II, April 1974.

Rogers, R. H., Reed, L. E., Shah, N. J., and V. E. Smith, "Computer Mapping of Turbidity and Circulation Patterns in Saginaw Bay, Michigan (Lake Huron) from ERTS Data," Proceedings of ASP-ACSM Convention at Washington, D. C., March 1975.

US Environmental Protection Agency, Office of Air and Water Programs, EPA-430/9-73-014, "Methods for Identification and Evaluation of the Nature and Extent of Non-Point Sources of Pollutants," October 1973.

US Environmental Protection Agency, Water Planning Division, (Draft) "Guidelines for Areawide Waste Water Treatment Management," May 1974.

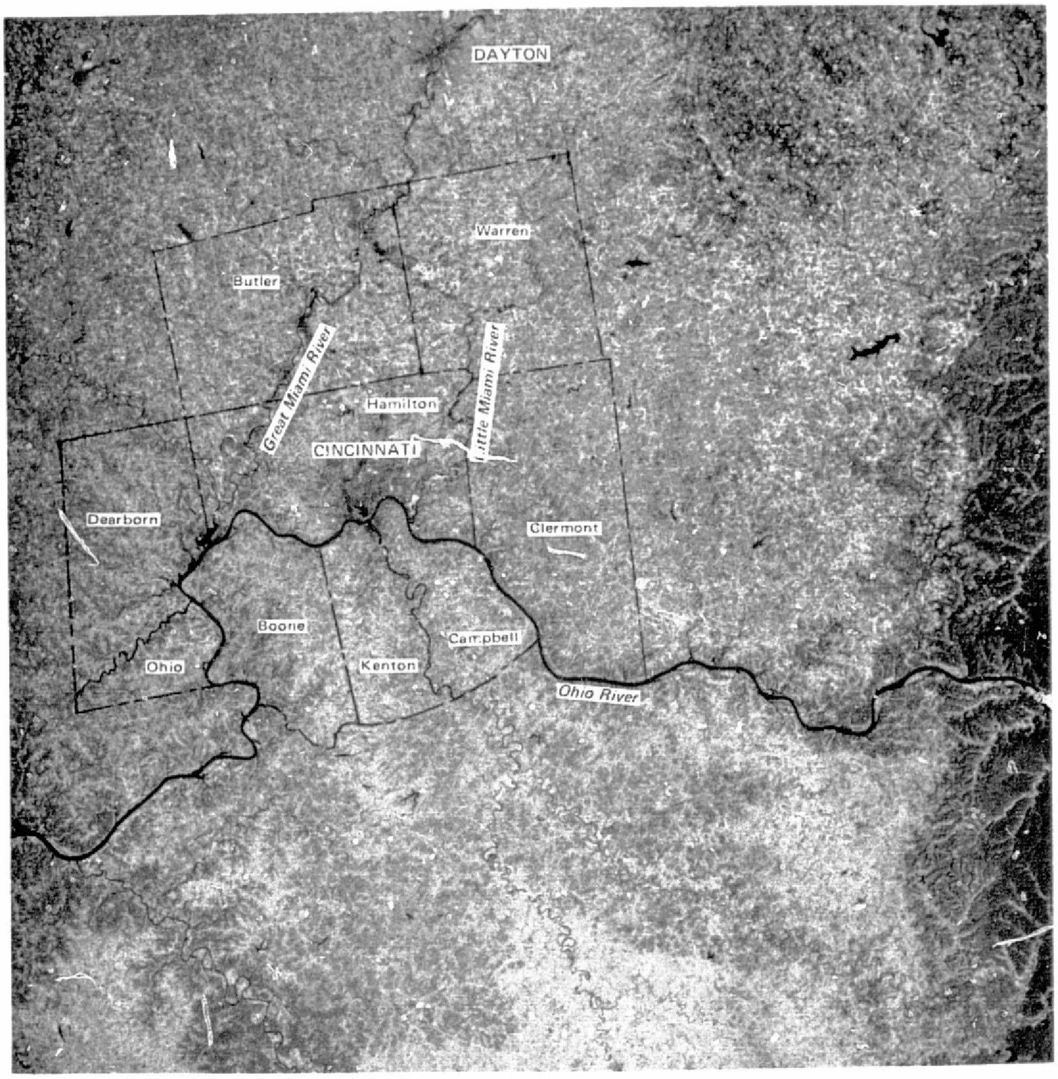
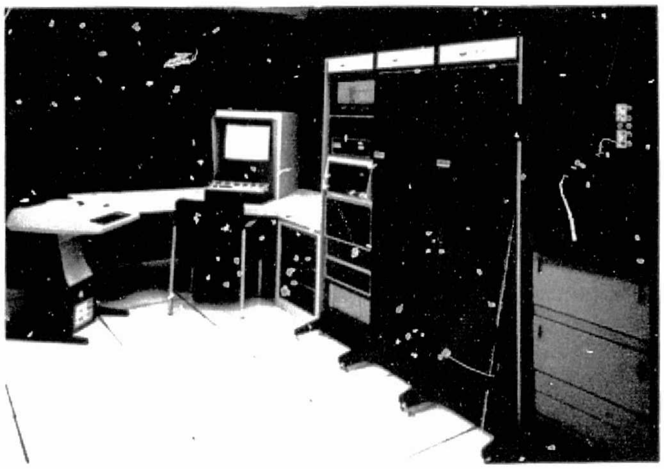


Figure 1. LANDSAT Band 7 Image (E-1265-15485) of 14 April 1973 Showing the Ohio-Kentucky-Indiana Regional Council of Governments Area.

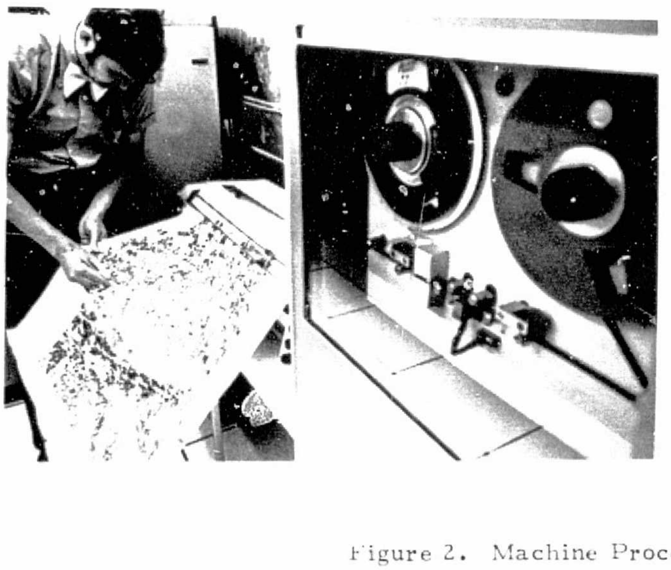
Develop Earth to LANDSAT Coordinate Transformation

- Digitize Ground Control Points
- Designate Location of Training Areas
- Digitize Boundaries of Areas for which Area Printout Tables Are Required; Watersheds, Counties, Townships, etc.



Produce LANDSAT Categorized Tapes

- Define Land-Water Categories and Locate Corresponding Training Areas within LANDSAT Tapes.
- Compute Category Characteristics.
- Evaluate Training Area Selection.
- Transform LANDSAT Tapes into New Set of Tapes where Each Pixel Is Coded to Correspond to Interpreted Land-Water Categories.



Generate Data and Map Products from LANDSAT Categorized Tapes

- Produce Transparent Color-Coded Overlay for Each Category; Typical Scales of 1:24,000, 1:62,500, and 1:250,000.
- Generate Color-Coded Imagery Where Color Is Used as a Code to Designate Categories.
- Produce Tabular Computer Printouts Listing Area Covered by Land-Water Categories within Specified Political and Geographic Boundaries in Percent Coverage per Category, Acres, and Square Kilometers.

Figure 2. Machine Processing of LANDSAT Data.

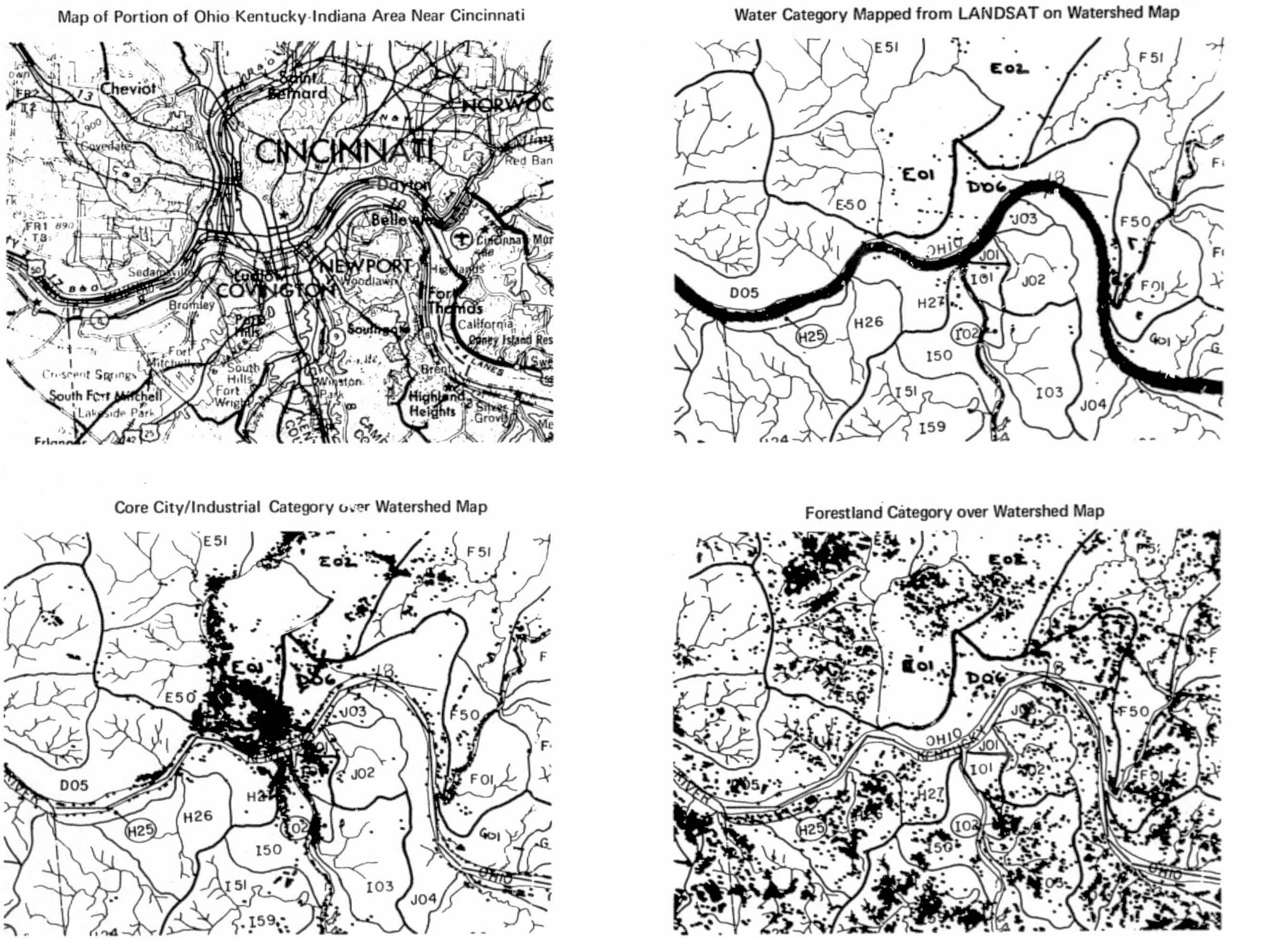
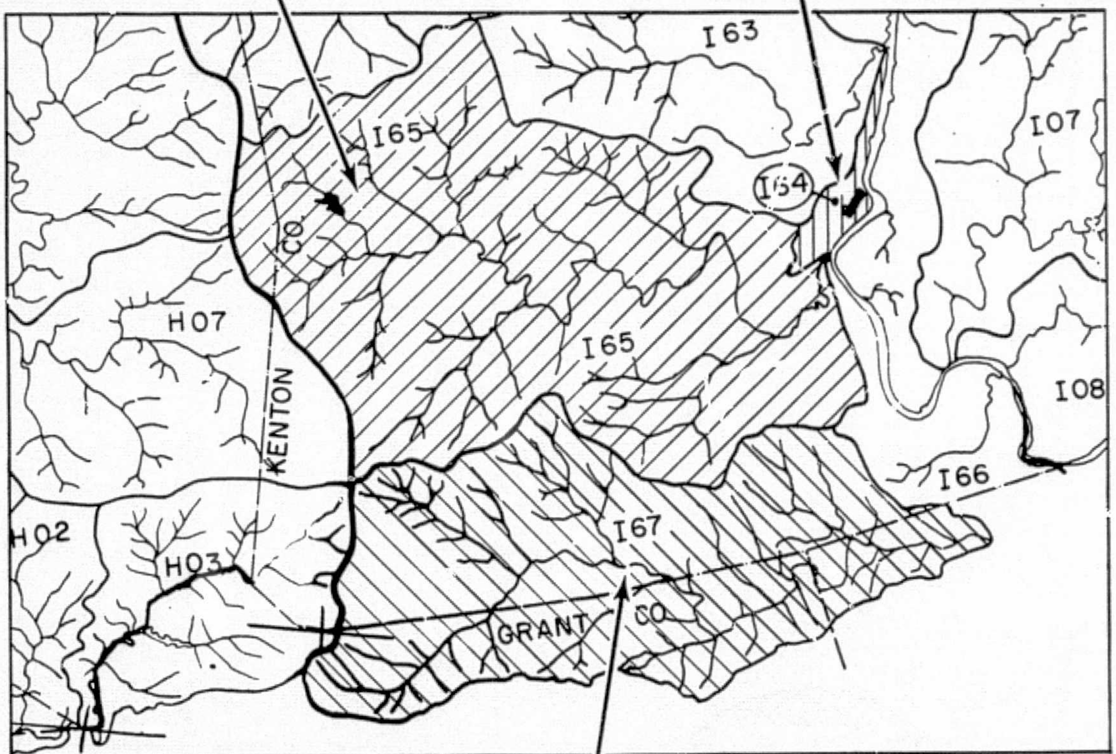


Figure 3. Examples of Land Use Mapped from LANDSAT Categorized Tapes (Original Scale: 1 inch = 2 miles).

Category	Percent of Watershed	Acres	Square Kilometers
Core City/Industrial	0.06	12.30	0.05
Inner City	0.14	27.95	0.11
Urban	5.97	1,200.62	4.86
Suburban	0.83	167.68	0.68
Cropland	2.16	435.98	1.76
Fallow Cropland	29.41	5,914.78	23.94
Rangeland	29.77	5,986.33	24.23
Forestland 1	13.23	2,660.59	10.77
Forestland 2	18.01	3,620.86	14.65
Water	0.03	4.47	0.01
Uncategorized	0.38	77.14	0.32
Total	100	20,108.70	81.38

Category	Percent of Watershed	Acres	Square Kilometers
Core City/Industrial	0.16	1.12	0.0
Inner City	0.16	1.12	0.0
Urban	8.2	58.13	0.24
Suburban	0.16	1.12	0.0
Cropland	1.73	12.29	0.05
Fallow Cropland	19.87	140.85	0.57
Rangeland	20.98	148.68	0.60
Forestland 1	24.45	173.27	0.70
Forestland 2	23.82	168.80	0.68
Water	0	0	0
Uncategorized	0.47	3.35	0.01
Total	100	708.75	2.87



Category	Percent of Watershed	Acres	Square Kilometers
Core City/Industrial	0.01	1.12	0.0
Inner City	0.01	1.12	0.0
Urban	6.58	960.27	3.89
Suburban	0.77	112.91	0.46
Cropland	1.59	231.41	0.94
Fallow Cropland	27.96	4,082.55	16.52
Rangeland	27.56	4,024.42	16.29
Forestland 1	13.01	1,900.42	7.69
Forestland 2	22.31	3,258.66	13.19
Water	0	0	0
Uncategorized	0.21	30.19	0.12
Total	100	14,603.07	59.10

Figure 4. Map of Watersheds in Southern Kenton County, Kentucky, and Tabular Printouts Produced from LANDSAT Categorized Tapes.